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Climate Change and its impact on Groundwater Table Fluctuation in Precambrian rocks of Chamarajanagara district, Karnataka, India using Geomatics technique

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ABSTRACT

Change in climatic conditions directly affects the hydrologic cycle and gradually the groundwater table. Rise in temperature increases the evaporation of surface water and transpiration in wetlands. This results in low precipitation amounts, timings and intensity rates; which impacts on surface water bodies (rivers and lakes) as well as subsurface water bodies (change in volume and distribution of groundwater recharge process) and direct changes in major long-term climate variables such as air temperature, moisture content, precipitation and evapo-transpiration. Geomatics encompasses Survey of India (SoI) Toposheets, Remote Sensing (RS) Satellite Images, Geographic Information Systems (GIS) and Global Positioning Systems (GPS) with limited Ground Truth Check (GTC). Efforts have been made to evaluate the data from 27 representative rain gauge stations and analyzed the season-wise rainfall variation over a period of 26 years (1984-2009). 36 representative well samples are considered to study the groundwater table fluctuation from season to season of about 12 years (1998-2009). The spatial variability of mean annual precipitation depends upon the topographic factors like exposure of station to the prevailing wind, elevation, orientation and slope of the hills/mountains. The average and mean rainfall over the area are calculated using arithmetic mean, thiessen polygon and iso-hyetal methods. Average rainfall is the simple arithmetic mean rainfall measured in the area; while Iso-hyetal method has been adopted for spatial distribution of rainfall with respect to a particular direction. Rain gauge stations are plotted on a base map with their respective amount of rainfall and then the contours of equal rainfall (isohyets) are drawn using Surfer v8.5. The different rainfall intervals obtained (area between the two adjacent lines) are helpful in understanding the variation of rainfall over the study area. The final results highlight the impacts of climatic change over groundwater table fluctuation in typical Precambrian rocks of Chamarajanagara District, Karnataka, which is a suitable model in similar geological conditions.

Keywords: Climate Change, Groundwater Table Fluctuation, Chamarajanagara, Geomatics.

1. Introduction

Rain is liquid precipitation that requires the presence of a thick layer of atmosphere to have temperatures above the melting point of water near and above the earth’s surface. The moisture moving along three dimensional zones of temperature and moisture contrasts known as weather. Rain forms when separate drops of water fall on earth’s surface from clouds. Not all rain reaches the surface; however, some evaporates while falling through dry air, a type of precipitation called Virga. Rain plays a major role in the hydrologic cycle in which from the oceans evaporates, condenses into clouds precipitates back to earth, and eventually returns to the ocean via streams and rivers to repeat the cycle again. Four conditions are necessary for the production of the observed amount of rainfall (Gilman and Charles S., 1964): a)

Mechanism to produce cooling of air, b) Mechanism to produce condensation, c) Mechanism to produce growth of cloud droplets, and d) Mechanism to produce accumulation of moisture of sufficient intensity to account for observation for rainfall. The precipitated water percolates to deeper zones in sub-surface and stored as groundwater. The occurrence, origin and distribution of groundwater are controlled by the nature of rock formation, geological structures, geomorphological and hydrometerological conditions. Geomatics application is an advent hi-tech tool for extraction, integration of information and its utilization for sustainable development on particular regions of the country especially in cases where resources lie hidden below the earth's surface at certain depths. Groundwater resources in hard rock terrain are limited which needs thorough estimation and development (Dinakar S., 2005, "a"; Dinakar et al., 2008) that has to be planned scientifically for a better management and sustainability (Basavarajappa et al., 2014; Pushpavathi and Basavarajappa., 2009), The rain gauge stations provide continuous record of rainfall, intensity, duration and are usually expressed in terms of centimeter (cm) or millimeter (mm),

2. Study area

It lies in between $11^0$30'45" to $12^0$22'00" N latitude and $76^0$30'45" to $77^0$42'30" E longitude with general elevation of 656.58 m above MSL. The total aerial extent is 5,685 Km^2 located in Southern tip of Karnataka State. It includes 4 taluks namely; Chamarajanagara, Gundlupete, Kollegala and Yalenduru (Figure 1), Kollegala is the largest of all taluks with an area of 2,785 Km^2 (49%) (Basavarajappa and Dinakar., 2005); while Yelanduru is the smallest with an area of 256 Km^2 (4.66%) of the district. The eastern and southern portion of Kollegala taluk forms continuous lofty hills such as Malai Mahadeshwara with an elevation of 976 m above MSL having 7 hill ranges and the prominent ranges are Anemale, Kadumale, Jenumale, Nagamale etc. Dodda Sampigae is another hill range runs N-S of about 6 Km in Kollegala taluk. Biligiri-Rangan hill in Yalenduru taluk, Gopalswamy hill in Gundlupete also forms the hill ranges in the district. Most of the area is covered by thick forest and parallel hill ranges of Western Ghats. The district is drained by Suvarnavathi and Chikkahole which are the tributaries of Cauvery River (Basavarajappa H.T., 1992; CGWB., 2008; Dinakar S., 2005,"a"; Dinakar and Basavarajappa., 2005,"b"; Satish M.V., 2002). The existence of forests provides raw materials for industries like paper, rayon, saw mills, safety matches and sandalwood.

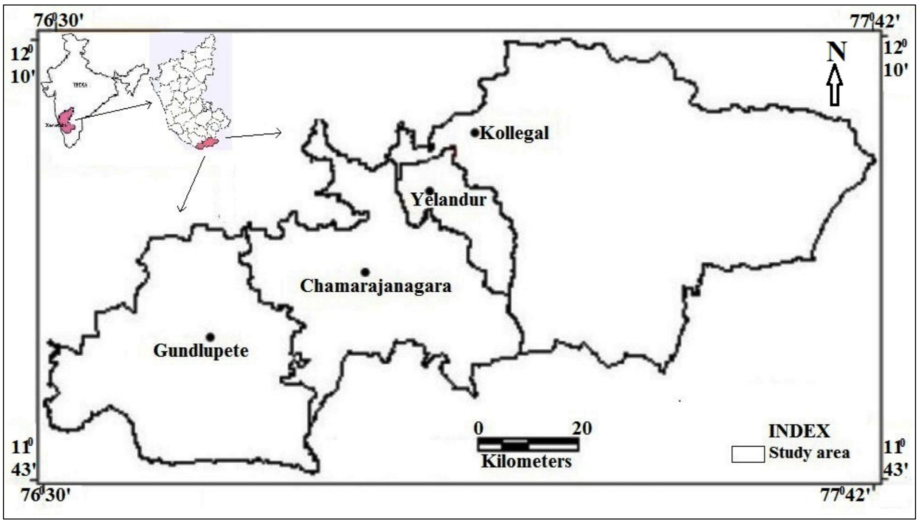


Figure 1: Location map of the study area

3. Climate

It is quite moderate throughout the year with fairly hot summer and cold winter (CGWB., 2008; Dinakar S., 2005,"a"). The climate is an essentially tropical monsoon type which is a product of the inter-play of two conflicting air masses of the SW and NE monsoons. Over the greater part of the district, summer is gradually gets warmer and winters bracingly gets cooler throughout the year.

3.1 Cool weather

The weather is comparatively dry except in the catchment of river areas. Cool weather season begins at the end of November and continues till the end of February with noticeable variations in day and night temperatures. January is the usual cold month recording the lowest temperature of 13.3^{0}C and later may rise up to 16.1^{0}C.

3.2 Warm weather

The temperature is high and ranges from 19.7°C - 35.1°C (March-May). Land surface becomes very hot and a wide range of variations between day and night temperatures.

3.3 Temperature

Temperature influences considerably on the socio-economic activities of the people of a region. The study area generally enjoys cool and calm weather, but there is a continuous rise in temperature during March to May. April being the hottest month of the year where the mean daily maximum temperature reaches to 34.5°C, while the daily minimum is 21.1°C. The temperature may exceed 39°C during summer in the month of March and April (Pushpavathi., 2010). However, there is an occasional relief from pre-monsoon thundershowers. After mid-November, both day and night temperature decreases. January is considerably the coldest month with mean daily maximum temperature of 11°C. Occasionally during November to January, the minimum temperature may go above the mean and daily maximum temperature recorded is 36.9°C (April-1998) and minimum temperature is 15.5°C (Dec-2003).

3.4 Humidity

In general, the relative humidity is high during SW monsoon season which rises during morning time throughout the year; while in the afternoon, it is comparatively low except during SW monsoon season. The humidity is very less with 35% and still lowers in the afternoons (Jan to April).

3.5 Methods and Materials

3.5.1 Methods

Rainfall data are collected by respective rain gauge stations and plotted on a base map with their respective amount of rainfall. Ground Truth Check (GTC) is done by GPS (Garmin 12) using geo-referenced Survey of India (SoI) toposheets (1:50,000) through Erdas Imagine v8.5. Contours of equal rainfall (isohyets) lines are drawn using Surfer v8.5. The average rainfalls between the successive isohyets are taken as the average of two iso-hyetal values. The different rainfall intervals obtained (area between two adjacent lines) are helpful in understanding the variation of rainfall over the study area. Annual average rainfall of iso-hyetal lines are plotted and digitized in meter level.

3.5.2 Materials

1. **Topomaps:** 57H/3, 57H/4, 57H/7, 57H/8, 57H/12, 57H/16, 57D/12, 57D/16, 57A/5, 57A/6, 57A/9, 57A/10, 57A/13, 57A/14, 57E/1, 57E/2, 57E/5, 57E/9.
   Source: Survey of India (SoI) of 1:50,000 scale, Bangalore.
2. **Rainfall** (1984 to 2009 - 26 years) and **Groundwater table data** (1998 to 2009 - 12 years).
   Source: Field survey and Ground Truth Check (GTC); Department of Mines and Geology (MGD), Chamarajanagara; Agriculture Science Department; Statistic Department; Meteorological Department, Pune; Karnataka State Remote Sensing and Application Centre (KSRSAC) Mysore.
3. **GIS Software's:** Erdas Imagine v8.5, ArcGIS v9.2, ArcView v3.2, Surfer v8.5 and Auto Cad v2004.
4. **GPS analysis:** Garmin 12 is used during field visits to check the exact locations of Rain gauge stations and Observation well points.

3.6 Rainfall

Rainfall is the main source for surface as well as sub-surface water bodies. The seasonal rainfall distribution and its reliability give an idea over local recharge that would influence the groundwater table fluctuation. The average annual rainfall recorded is 1,238.23mm (2009) and SW monsoon contributes to a large extent of 44.44%. About 26 years (1984-2009) of rainfall data from 27 representative Rain gauge stations data have been collected and analyzed for Rainfall variation. The rain gauge stations considered in the study area are Chamarajanagara, Mangala, Haradanahalli, Kuderu, Ummathuru, Suvarnavathi, Udigala, Kagalavadi, Gundlupete, Beguru, Therakanambi, Kundukere, Bandipura, Moolehole, Mookhahalli, Hangala, Kollegala, Mudigundum, Shagya, Martalli, Byluru, Malai Mahadeshwara hills, Gajanuru, Gundal, Lokkanahalli, Yelanduru and Biligiri-Rangan hills are analyzed for monthly rainfall distribution analysis (Figure 2; Table.1).

3.7 Spatial distribution of rainfall

The spatial variability of mean annual precipitation depends upon the topographic factors such as exposure of station to the prevailing wind, elevation, orientation and slope of the mountain (Basist and Bell., 1994; Dinakar S., 2005,"a"; Pushpavathi K. N., 2010; Satish M.V., 2002), Arithmetic mean, Thiessen polygon and Iso-hyetal methods are adopted in the present study.

Arithmetic mean is used for measurements of selected duration at all rain gauges are summed and the total is divided by the number of gauges. Arithmetic method is the simplest objective methods of calculating the average rainfall over an area.

Thiessen polygon method provides the individual areas of influence around each set of points. Thiessen polygons are the polygons whose boundaries are mathematically define the area (perpendicular bisectors) that is closest to each point relative to all other points. Thiessen (1911), an American engineer adopted the polygon method for rainfall measurements at individual gauges as first weighted by the fractions of the catchment area represented by the gauges, and then summed.

Iso-hyetal method is a line drawn on a map connecting points that receive equal amounts of rainfall. It's a convenient method that views continuous spatial variation of rainfall area. The main aim of the method is to draw lines of equal rainfall amount (isohyets) using observed amounts at stations (Reed and Kincer., 1917). The average depth is then determined by computing the incremental volume between each pair of isohyets; adding these incremental amounts and dividing by the total area. In iso-hyetal map, the x-axis represents East Longitude, while y-axis represents North Latitude.

3.8 Seasonal distribution of rainfall

Monsoon season contributes the major portion of annual rainfall over the Cauvery basin (Subramanyam and Venkatesh., 1983). Seasonal rainfall data is very important for many instances such as agricultural activities, irrigation, ground water recharge, its management, development and sustainability. The rainfall of the study area in a year is divided into three seasons namely; Pre-monsoon, Monsoon and Post monsoon (Bureau of Economics and Statistics, Govt. of Karnataka). The study area receives very low amount of rainfall during Pre-monsoon season, while it receives most of the annual rainfall during Monsoon and Post monsoon seasons.

3.9 Season-wise analysis of rainfall

3.9.1 Pre-Monsoon

It starts from January and ends in the month of May receiving an average rainfall of 194.75 mm. The minimum rainfall received in Gajanuru is about 76.38 mm (17.04%); while maximum in Moolehole of about 292.77 mm (25.11%). The iso-hyetal map of pre-monsoon season depicts that the rainfall is decreasing from SE to NW in the study area (Figure 3).

3.9.2 Monsoon

Any region that receives the majority of its rainfall during a particular season also called as South west monsoon season (June to Sept). The average rainfall is about 334.82 mm (42%) and provides maximum contribution for normal annual rainfall. The minimum rainfall received in Gajanuru rain gauge station is about 181.25 mm (4.43%) and maximum rainfall is received in Biligiri-Rangan temple of 652.04 mm (53.79%). The iso-hyetal map of the season depicts that the rainfall is decreasing from SE to West in the study area (Figure 4).

3.9.3 Post Monsoon

North-East monsoon occurs in the month of October to December. Most of the rainfall during post monsoon is closely associated with the westward passage of storms and depressions that are remnants of low pressure systems moving into the Bay of Bengal (Das., 1995). The average rainfall in this season is 261.88 mm which contribute 33.45% to normal annual rainfall. The minimum rainfall is recorded in Ummathuru is about 183.67 mm (27.36%) and maximum rainfall is 398.09 mm (39.65%) in Malai Mahadeshwara hill. The iso-hyetal map of the season depicts that the rainfall is decreasing from East to NW of the study area (Figure 5).

3.9.4 Annual rainfall

The annual rainfall varies from 649.73 mm (Haradanahalli) to 1212.20 mm (Biligiri-Rangan Temple) and the average normal rainfall is 791.44 mm (Figure 6). The iso-hyetal map of 26 years normal rain gauge stations data indicates that the rainfall decreases from East to Northern part of the study area. The rainfall is low mainly in pre-monsoon season that affects the vegetation activities (Figure 7 and 8).

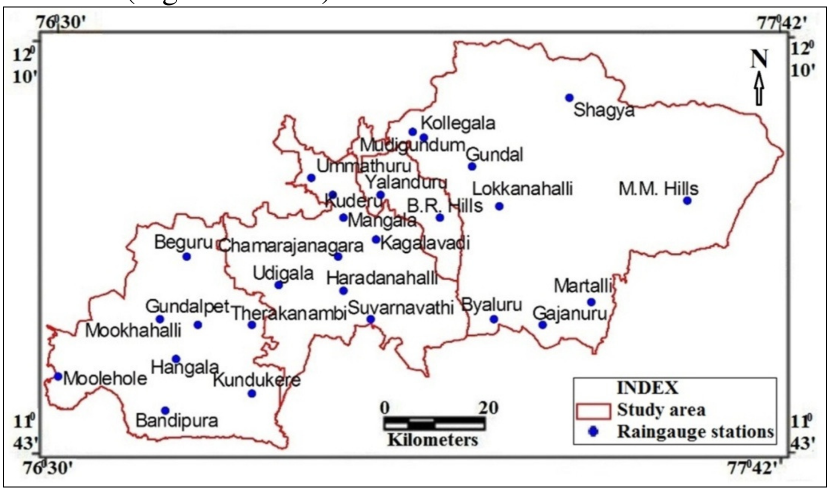


Figure 2: Rain-gauge stations of the study area

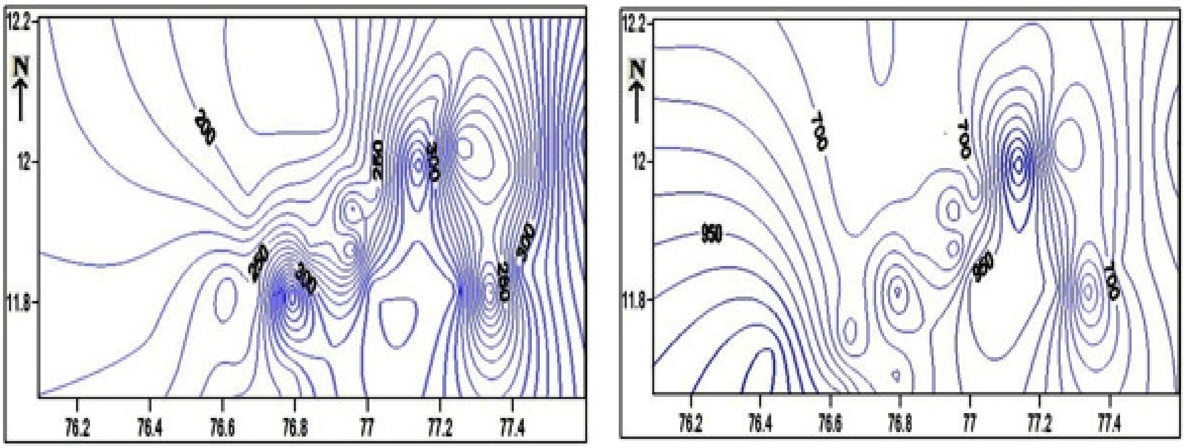


Figure 3 and 4: Pre-monsoon and Monsoon rainfall iso-hyetal map

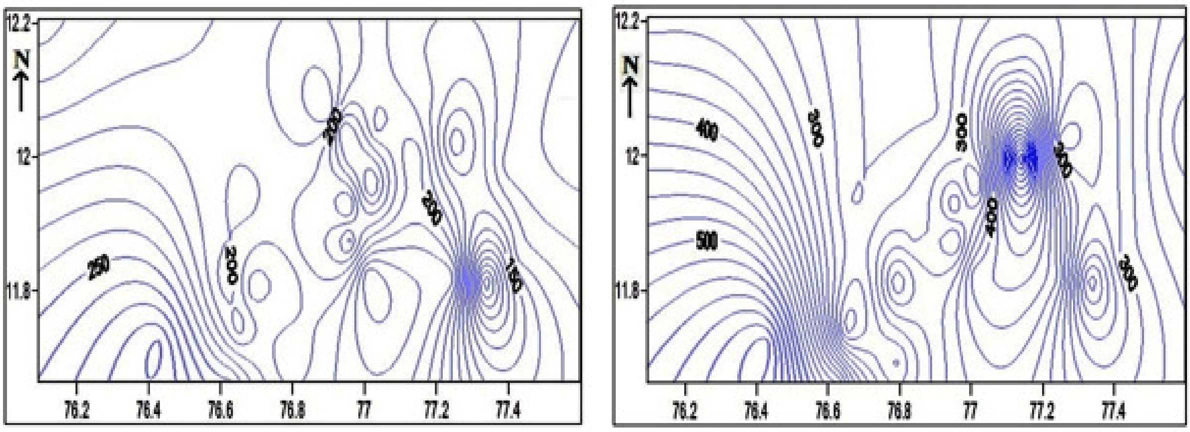


Figure 5 and 6: Post-monsoon and Annual rainfall iso-hyetal map

Table 1: Season-wise normal rainfall data (1984-2009) (Iso-hyetal maps)

Sl No	Village name	Pre-monsoon (mm)	Percentage	Monsoon (mm)	Percentage	Post-monsoon (mm)	Percentage	Annual (mm)
1.	Chamarajanagara	217.75	25.32	361.93	42.09	280.18	32.58	859.86
2.	Mangala	163.14	24.03	298.27	43.94	217.43	32.03	678.84
3.	Haradanahalli	163.52	25.17	273.69	42.12	212.51	32.71	649.73
4.	Kuderu	158.78	24.65	281.53	43.72	203.71	31.63	644.02
5.	Ummathuru	229.86	34.24	257.74	38.40	183.67	27.36	671.28
6.	Suvarnavathi	250.42	25.26	414.45	41.80	326.68	32.95	991.55
7.	Udigala	192.20	26.35	297.28	40.76	239.94	32.90	729.42
8.	Kagalavadi	144.81	22.06	271.03	41.29	240.56	36.65	656.40
9.	Gundalpet	228.50	31.26	254.42	34.81	247.97	33.93	730.89
10	Beguru	196.45	29.94	257.56	39.25	202.12	30.81	656.13
11	Therakanambi	217.62	22.27	382.84	39.17	376.84	38.56	977.30
12	Kundukere	201.56	27.39	252.56	34.32	281.87	38.30	735.99
13	Bandipura	252.12	26.23	438.33	45.60	270.80	28.17	961.26
14	Moolehole	292.77	25.06	632.72	54.15	242.98	20.79	1168.47
15	Mookhahalli	192.12	25.11	302.34	39.51	270.72	35.38	765.18
16	Hangala	193.31	28.94	223.77	33.50	250.88	37.56	667.96
17	Kollegala	181.16	23.47	337.34	43.70	253.40	32.83	771.90
18	Mudigundum	172.82	23.87	329.78	45.55	221.40	30.58	724.00
19	Shagya	194.86	27.20	293.72	41.00	227.85	31.80	716.43
20	Martalli	172.02	21.67	307.33	38.71	314.57	39.62	793.92
21	Byaluru	226.22	24.35	380.00	40.90	322.77	34.74	928.99
22	M.M. Hills	207.45	20.66	398.56	39.69	398.09	39.65	1004.10
23	Gajanuru	76.38	17.04	181.25	40.43	190.66	42.53	448.29
24	Gundal	178.36	21.63	355.07	43.06	291.18	35.31	824.60
25	Lokkanahalli	140.58	23.86	248.57	42.19	200.04	33.95	589.20
26	Yalanduru	204.17	25.17	355.98	43.89	250.92	30.94	811.07
27	B.R. Hills	209.20	17.26	652.04	53.79	350.96	28.95	1212.20
	Average	**194.75**		**334.82**		**261.88**		**791.44**

Table 2: 26 years Average of season-wise rainfall data (1984-2009)

Sl No.	Year	Pre-monsoon	Monsoon	Post-monsoon	Annual
1.	1984	153.01	321.84	227.84	488.91
2.	1985	132.42	347.21	143.61	464.24
3.	1986	127.23	339.51	229.92	489.21
4.	1987	98.28	369.52	399.20	507.12
5.	1988	126.91	463.02	97.84	467.10
6.	1989	113.41	409.61	214.30	469.21
7.	1990	104.24	163.84	239.00	321.79
8.	1991	137.02	469.58	353.61	537.24
9.	1992	117.32	451.95	249.44	507.21
10.	1993	108.62	289.01	339.30	489.20
11.	1994	167.52	263.00	409.95	540.21
12.	1995	114.17	383.30	182.16	450.12
13.	1996	119.71	479.85	248.95	503.21
14.	1997	137.20	303.28	361.50	507.89
15.	1998	193.39	412.61	378.61	810.24
16.	1999	137.81	263.51	369.93	497.89
17.	2000	178.12	479.11	284.18	561.23
18.	2001	126.09	309.20	253.24	492.31
19.	2002	218.28	226.88	234.61	810.27
20.	2003	223.61	209.14	207.30	857.20

21.	2004	193.34	339.61	227.61	498.25
22.	2005	498.07	311.30	429.43	1994.24
23.	2006	82.17	183.80	157.00	312.08
24.	2007	67.11	263.39	202.33	298.25
25.	2008	79.05	117.31	21.59	153.27
26.	2009	289.21	593.51	118.68	1238.23

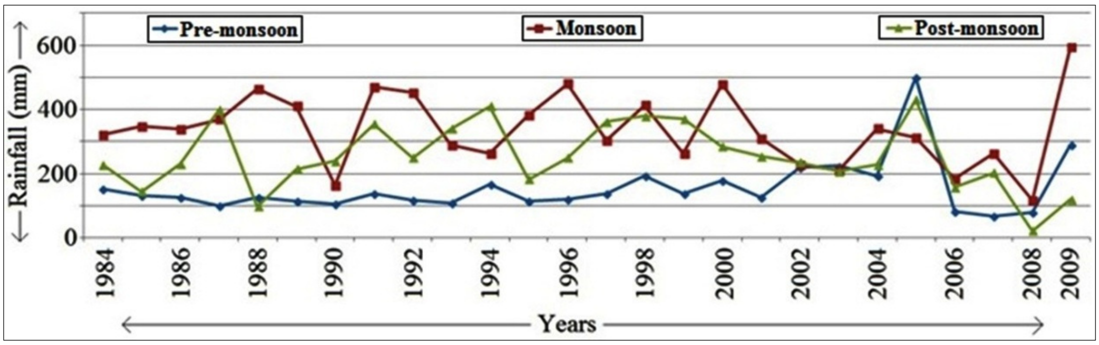


Figure 7: Season-wise Rainfall fluctuation trend analysis of 26 years (1984-2009)

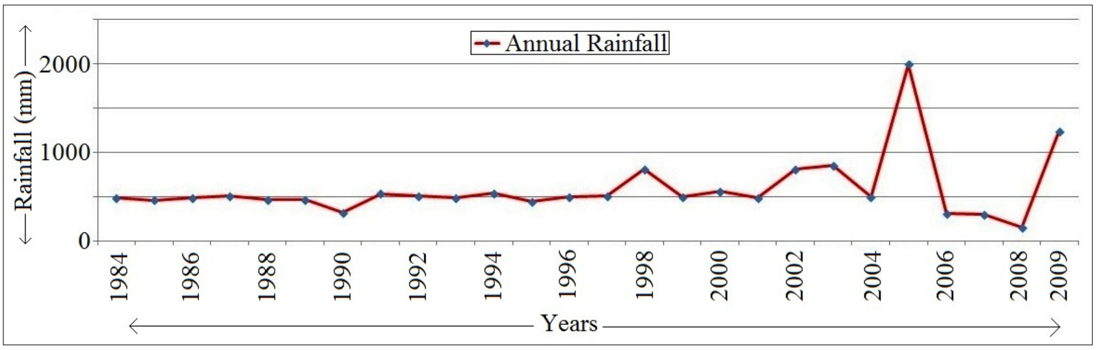


Figure 8: Annual Rainfall fluctuation trend analysis of 26 years (1984-2009)

3.10 Water Table

The water table refers to the elevation of water surface in wells which cover only the shallow depth region of the aquifer zone (Davis and DeWiest., 1970). The water contained in interconnected pores, gaps or fractures located below the water table in an unconfined/confined aquifer (Craig Clifton et al., 2010). Groundwater recharge occur mainly due to direct infiltration through soil pore spaces, fractures of lithologic formations, in some places adjacent to the river and canal irrigated areas also by irrigation water (Basavarajappa et al., 2014; Dinakar et al., 2008). An aquifer is a unit of rock or an unconsolidated deposit that can yield a usable quantity of water (Pushpavathi K.N., 2010). Fluctuation in groundwater table occurs due to seasonal moisture variation, water absorption by vegetation, evapo-transpiration in wetlands and withdrawal of groundwater from bore wells.

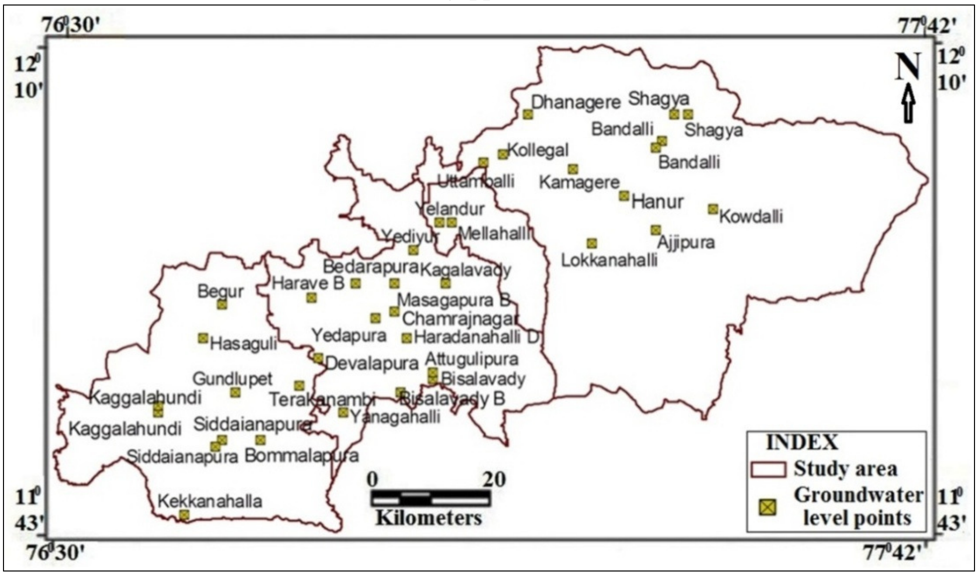


Figure 9: Observation bore well points of the study area

The usable groundwater resource is essentially a dynamic resource which is recharged annually or periodically by rainfall, irrigation returns flow, canal seepage and influent seepages etc. The magnitude of the groundwater table fluctuation depends on climatic factors, drainage, topography and geological conditions. Water table also declines due to heavy withdrawal of groundwater through pumping wells. Near the river/streams, groundwater table fluctuates in response to the change in the level of river stage. There are various methods in use for the quantitative evaluation of groundwater recharge (Thornthwaite and Mather., 1957) such as water table fluctuation and specific yield method, rainfall infiltration method and soil moisture balance method.

3.11 Groundwater table fluctuation

The water table fluctuation method provides a point value of recharge, computed from the water level rise in a well and multiplied by the specific yield of an aquifer. An accurate estimation of a spatial and temporal fluctuation of a groundwater table is of prime importance in the management of subsurface water resource (Rai and Singh., 1985). The groundwater is naturally replenished by surface water from precipitation, streams and rivers. In the present study, 36 representative bore wells have been considered as observation points such as., Bisalavady, Attugulipura, Bedarapura, Harave, Bommalapura, Siddaianapura, Kaggalahundi, Shagya, Kowdalli, Kollegal, Lokkanahalli, Bandalli, Mellahalli, Masagapura, Yedapura, Haradanahalli, Yediyuru, Kagalavady, Chamarajanagara, Gundlupete, Terakanambi, Hasaguli, Hanuru, Ajjipura, Kamagere, Yelanduru, Devalapura, Yanagahalli, Siddaianapura, Beguru, Kaggalahundi, Kekkanahalla, Uttamballi, Bandalli and Dhanagere; to analyze the groundwater table fluctuation from season to season (Figure 9; Table.3). Once in a month, the groundwater levels in all observation wells are recorded. Seasonal and annual fluctuations in groundwater level are collected and analyzed over a period of 12 years (1998-2009). The minimum water level observed is 2.55m at Devalapura observation well and the maximum is 30.78m at Gundlupete observation well. Ferdowsian (2001) presented a new approach call Hydrograph Analysis, Rainfall and Time Trends (HARTT) for statistically estimating groundwater levels. Their method differentiates between the effect of rainfall fluctuations and the underlying trend of groundwater levels over time.

3.12 Pre-Monsoon groundwater table fluctuation

The groundwater table variation in pre-monsoon season ranges from 3.53m to 30.17m with an average of 13.07m. Groundwater table fluctuation is high in south western parts of the study area and occurs as isolated patches while is low in eastern and north-eastern parts (Figure 10).

3.13 Monsoon groundwater table fluctuation

The groundwater table variation during south-west monsoon ranges from 2.93-30.78m with an average of 14.08m. The groundwater table is high in western and northern parts, but the exploitation of groundwater is seems to be very high in eastern parts of the study area (Figure 11).

3.14 Post Monsoon groundwater table fluctuation

The groundwater table variation during south-west monsoon ranges from 2.55 to 30.65 m. The general trend of groundwater table is high in eastern and central parts of the study area. Generally, the groundwater table rises at the end of rainy season, gets lowered progressively and reaches the lowest level as the summer season advances (Figure 12).

3.15 Annual groundwater table fluctuation

The annual average groundwater depth depicts that the water table depth is high in eastern, central and southern parts of the study area (Figure 13). However, gneissic rocks are highly weathered and slope varies from nearly level to very gentle slope providing a good agriculture activities. The annual average groundwater table ranges from 3.28 to 30.49 m. Though the rainfall is very high in Biligiri-Rangan hill station, but the groundwater table depth is high due to its topography, steep slopes and high runoff (Figure 15). On other hand, groundwater table remains constant in northeast and northwestern parts in all the seasons due to the perennial Cauvery River (Figure 14). Groundwater discharge takes place primarily through artificial withdrawal of water from bore wells and to a lesser extent through lateral flow to lower sections contributing to the base flow in streams and rivers.

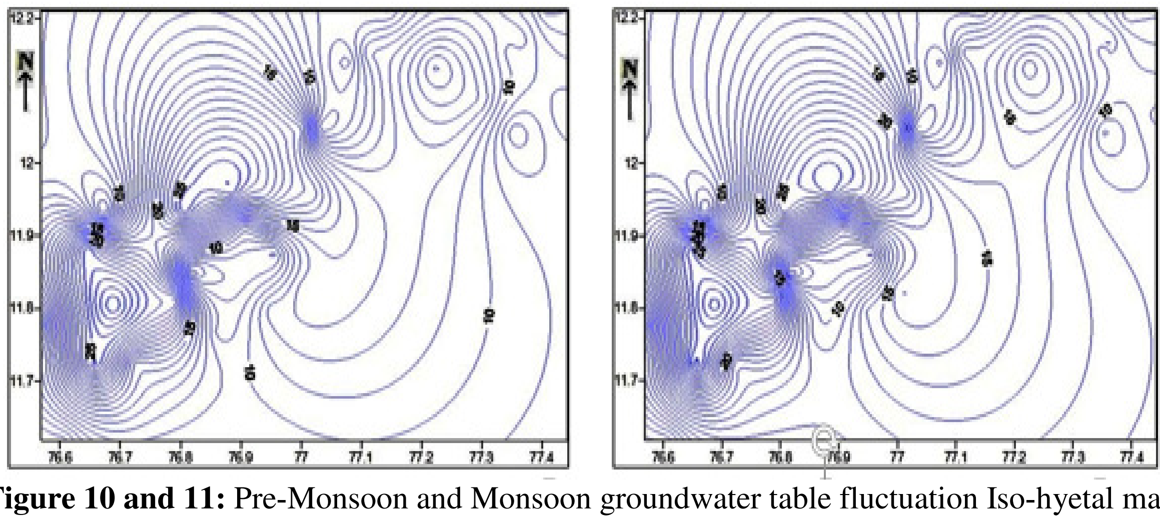
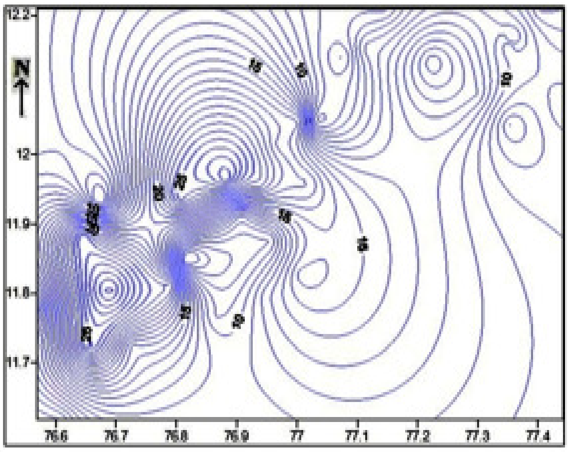


Figure 10 and 11: Pre-Monsoon and Monsoon groundwater table fluctuation Iso-hyetal map



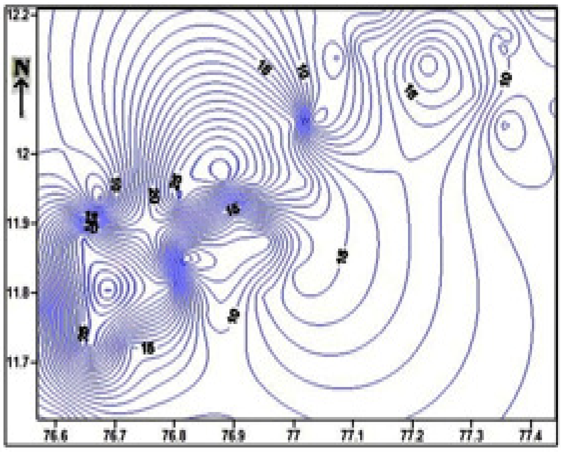


Figure 13 and 14: Post monsoon and Annual groundwater table fluctuation Iso-hyetal map

Table 3: Season-wise normal rainfall data (1998-2009) (Iso-hyetal maps)

Sl No	Village Name	Pre-monsoon (m)	Monsoon (m)	Post-monsoon(m)	Annual (m)
1.	Bisalavady	12.48	14.12	12.56	13.05
2.	Attugulipura	13.72	17.06	16.48	15.53
3.	Bedarapura	26.99	27.96	28.78	27.76
4.	Harave	27.12	26.09	25.80	26.45
5.	Bommalapura	14.45	15.01	15.81	14.98
6.	Siddaianapura	26.41	28.81	26.37	27.20
7.	Kaggalahundi	7.31	6.99	6.32	6.96
8.	Shagya	5.72	7.60	5.73	6.35
9.	Kowdalli	9.98	11.38	9.86	10.42
10.	Kollegal	11.10	13.43	10.39	11.70
11.	Lokkanahalli	12.57	13.96	12.49	13.01
12.	Bandalli	11.40	12.73	12.66	12.16
13.	Mellahalli	17.89	19.59	18.14	18.52
14.	Masagapura	22.40	24.56	22.56	23.16
15.	Yedapura	10.47	11.25	9.74	10.55
16.	Haradanahalli	6.59	6.45	7.80	6.84
17.	Yediyur	20.63	22.15	18.63	20.64
18.	Kagalavady	18.79	20.21	19.21	19.37
19.	Chamrajnagar	15.68	16.43	14.54	15.64
20.	Gundlupet	30.17	30.78	30.65	30.49
21.	Terakanambi	24.15	25.77	23.00	24.40
22.	Hasaguli	25.72	27.73	25.97	26.45
23.	Hanur	13.71	15.32	13.91	14.30
24.	Ajjipura	6.14	7.72	5.91	6.61
25.	Kamagere	17.36	18.75	17.92	17.96
26.	Yelandur	6.10	6.67	5.31	6.09
27.	Devalapura	3.53	3.53	2.55	3.28
28.	Yanagahalli	8.57	10.08	8.93	9.16
29.	Siddaianapura	7.12	7.90	7.37	7.44
30.	Begur	4.44	4.39	2.93	4.05
31.	Kaggalahundi	6.69	6.50	5.55	6.34
32.	Kekkanahalla	5.52	5.21	4.89	5.25
33.	Uttamballi	5.42	6.58	4.73	5.64
34.	Bandalli	8.95	10.22	9.10	9.41

35.	Dhanagere	6.79	8.10	6.49	7.15
36.	Shagya	7.32	7.09	6.94	7.15

Table 4: Season-wise Average of 12 years observation bore wells data (1998-2009)

Sl.No	Year	Pre-monsoon	Monsoon	Post-monsoon	Annual
1.	1998	33.17	28.91	18.91	81.28
2.	1999	36.91	34.78	22.10	54.91
3.	2000	46.71	50.91	26.81	121.80
4.	2001	45.31	44.78	27.51	113.20
5.	2002	52.1	57.21	47.51	153.11
6.	2003	88.12	71.02	53.62	207.21
7.	2004	93.25	73.29	52.19	217.01
8.	2005	94.29	70.03	36.51	201.87
9.	2006	63.54	56.81	42.61	155.82
10.	2007	78.91	63.19	45.78	182.01
11.	2008	76.21	64.01	43.91	179.89
12.	2009	71.90	58.69	52.61	181.29

3.16 Declination of water table

"Groundwater depletion, a term often defined as long-term water table declines caused by sustained ground water pumping". Groundwater is a primary source of fresh water and is being consuming faster than it's naturally replenished causing decline in water table unremittingly. It is essential to maintain a proper balance between the groundwater quantity and its exploitation which may later leads to large scale decline of groundwater levels; ultimately cause a serious problem for sustainable agricultural production and intern the area becomes wastelands (Basavarajappa et al., 2014; Pushpavathi and Basavarajappa., 2009; Pushpavathi K.N., 2010),

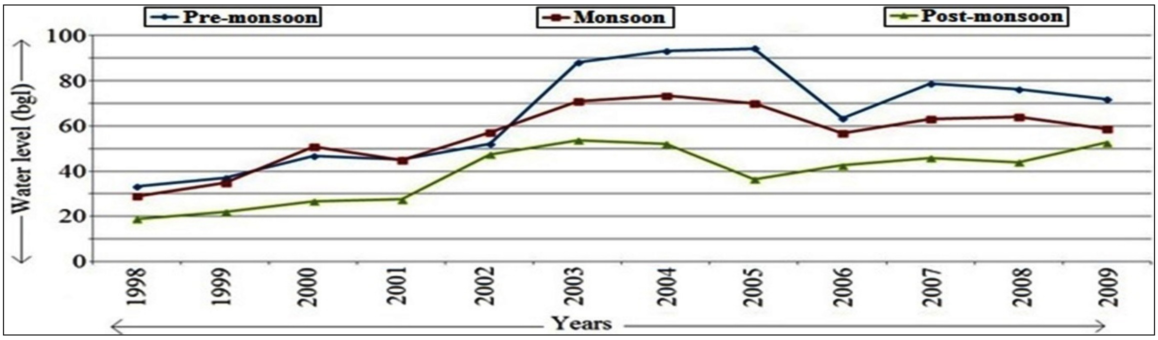


Figure 15: Season-wise Groundwater level fluctuation analysis of 12 year (1998-2009)

4. Results and Discussion

The main source of groundwater recharge is through precipitation and the occurrence and movement of groundwater is fully controlled by hydrological, hydrogeological and climatological factors. Though the maximum rainfall is received in Biligiri-Rangan hill station, the groundwater prospect is poor, since the topography and land pattern does not favor for infiltration. Rise and fall in groundwater table also depends on variability in topography, aquifer characteristics, vegetation dynamics as well as human activities. 26 years of season-wise rainfall data of 27 representative rain gauge stations have been collected; analyzed and respective iso-hyetal rainfall maps have been prepared. Rise in temperature by 1ºC to 2ºC will affects the groundwater recharge of about 10-15% depending upon the nature of rock formations, geological structures, geomorphological conditions and may varies in different geological conditions.

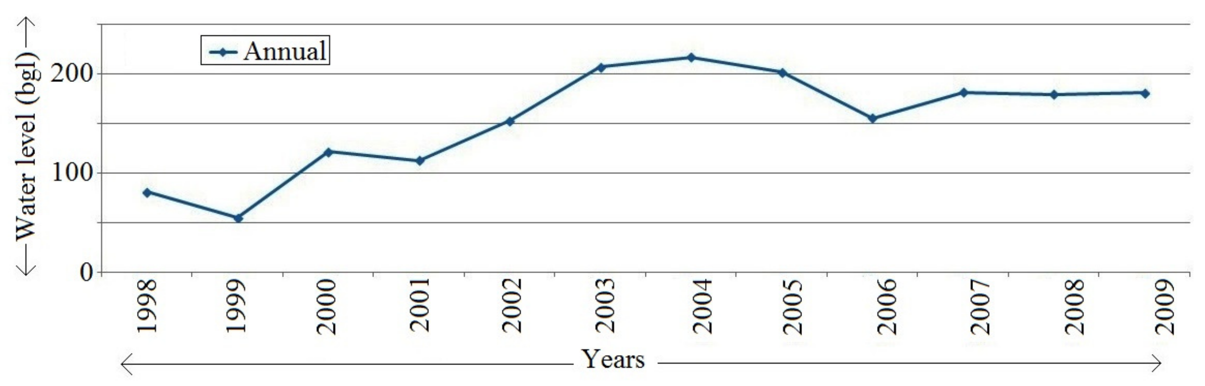


Figure 16: Annual Groundwater level fluctuation analysis of 12 year (1998-2009)

5. Conclusions

Rainfall is the main sources of water in the study area. The average rainfall over the study area is 1238.23 mm and monsoon rainfall contributes to a large extent of about 44.44%. The annual minimum rainfall of 649.73 mm is received in Haradanahalli rain gauge station and maximum rainfall of 1212.20 mm in Biligiri-Rangan hill rain gauge station. The iso-hyetal map of 26 years normal average annual rainfall indicates that the precipitation decreases from east to northern parts of the study area.

The main source of ground water occurring in the district is through precipitation and return flow from applied irrigation that occurs in fractures, fault zones and major lineaments in Precambrian older metamorphic rocks (Kollegal Shear Zone) of crystalline rocks under semi-confined to confined conditions. The groundwater prospect is low, since the topography and land pattern does not favor for infiltration. Selections of site for bore well should be done only on scientific methods for accurate and effective results. It is necessary to conserve water resources to enhance their capacity and increase in its supply to provide higher levels of environmental services especially during summer. Methods like crop rotations and constructions of Artificial Recharge Structures (ARS) in suitable sites may also help in good groundwater recharge. The water table has a wide variation between 2.55 m to 30.78 m. The low-lying areas show least; while the drainage dividing areas show maximum fluctuation in groundwater level.

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6. References

1. Basavarajappa H.T (1992), Petrology, Geochemistry and Fluid inclusion studies of Charnockite and Associated rocks around Biligiri-Rangan Hills, Karnataka, India, Unpub. thesis, University of Mysore, pp 1-108.

2. Basavarajappa H.T and Dinakar S (2005), Land use and land cover studies around Kollegal taluk, Chamarajanagar District using Remote Sensing and GIS techniques, Indian Mineralogists, 1(1), pp 89-94.

3. Basavarjappa H.T, Manjunatha M.C and Jeevan L (2014), Application of Geoinformatics in Delineation of Groundwater Potential Zones of Chitradurga District, Karnataka, India, International Journal of Computer Engineering and Technology, 5(5), pp 94-108.

4. Basist A and Bell G.D., (1994), Statistical relationships between topography and precipitation patterns, Journal of Climate, 7, pp 1305-1315.

5. Central Ground Water Board (2008), Ground water information booklet Chamarajanagar district, South Western region, Bangalore.

6. Craig Clifton, Rick Evans, Susan Hayes, Rafik Hirji, Gabrielle Puz and Carolina Pizarro (2010), Water and Climate Change: Impacts on groundwater resources and adaptation options, Water Working Notes, 1, pp 1-76.

7. Das P.K., (1995), The monsoons (National book trust of India), pp 1-88.

8. Davis S. N. and DeWiest, R. J. M, (1970), Hydrogeology. John Wiley and Sons Inc., New York, USA.

9. Dinakar S (2005,"a"), Geological, Geomorphological and land use/land cover studies using Remote Sensing and GIS around Kollegal Shear Zone, South India, Unpub. thesis, University of Mysore, pp 1-191.

10. Dinakar. S, and Basavarajappa .H.T, (2005,"b"), Land use and land cover studies around Kollegal, Chamarajanagar District using Remote Sensing and GIS techniques, the Indian Mineralogists., 1(1), pp 89-94.

11. Dinakar S., Basavarajappa H.T., Nagesh D., Satish M.V and Honnegowda H (2008), Mapping of groundwater potential zones through RS and GIS in Yelandur taluk, Remote Sensing and GIS Applications, University of Mysore, Edited Volume, 1(1), pp 168-178.

12. Ferdowsian R.D.J, Pannell C, Mc Carron, Ryder A and Crossing L., (2001), Explaining groundwater hydrographs, separating typical rainfall events from time trends, Australian Journal of Soil Research, 39, pp 861-875.

13. Gilman and Charles S., (1964), Handbook of applied hydrology compendium of water resources technology, Mc Graw-Hill Book Company, New York, pp 9-68.

14. Pushpavathi K.N and Basavarajappa H.T (2009), Remote Sensing and GIS applications for wasteland identification - A case study in Kollegal Taluk, Chamarajanagar District, Karnataka, India, Journal of Environmental Geochemistry,12(1), pp 13-18.

15. Pushpavathi K.N (2010), Integrated, Geomorphological study using Remote Sensing and GIS for development of wastelands in Chamarajanagar district, Karnataka, India, Unpub. Thesis, University of Mysore, Mysore, pp 1-201.

16. Rai S.N and Singh R.N., (1985), Water table fluctuation in response to time varying recharge, scientific basis for water resources management IAHS publ, September, No.153.

17. Reed W.G and Kincer J.B (1917), the preparation of precipitation chart, Monthly Weather Rev., Vol.45, pp 233-235.

18. Satish M.V (2002), Geomorphological impacts of tectonic movements in and around Biligiri-Rangan hill ranges, Karnataka, India, Unpub. Thesis, University of Mysore, pp 1-83.

19. Subramanyam V.P and Venkatesh H., (1983), Hydrometeorology of Kavery river basin-A climate study of rainfall and potential evapotranspiration, Proc. Sem. Hydrology, 8-10th June, Osmania Univ., Hyderabad, pp 95-110.

20. Thiessen A.H., (1911), Precipitation for large areas, Monthly Weather Revision, 39, pp 1082-1084.

21. Thornthwaite C.W and Mather J.R., (1957), The water balance, Climatology, Lab. Climatology, Centeron, New Jersey, 8(1).